MATHEMATICS DESIGN TECHNOLOGY IN THE PRACTICE OF LAO WEAVING

TECNOLOGIA NOS DESENHOS MATEMÁTICOS NA PRÁTICA DA TAPEÇARIA DE LAOS

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ABSTRACT

Weavers in the Lao People's Democratic Republic (Laos PDR) often use a complex heddle system to store and replicate their two dimensional geometric woven designs. In this paper, I briefly describe the weaving practices of one family of weavers, in order to demonstrate how a daughter was able to use the design storage system encoded by her mother in order to learn her practices of weaving at a time of need after her passing. I present in detail the operation of the Lao handloom technology, describing how the parts of the system enable the production, storage, retrieval and transfer of complex two dimensional geometric supplemental weft textile designs among members of a community of practice.

Keywords: Ethnomathematics; Textile; Design; Data Storage; Situated Learning.

RESUMO

Os tecelões na República Democrática Popular do Laos (RDP do Laos) frequentemente utilizam um sistema complexo de pentes para armazenar e replicar os dois desenhos de tecidos geométricos tridimensionais. Neste artigo, descrevo brevemente as práticas de tecelagem de uma família de tecelões visando demonstrar como uma filha foi capaz de utilizar o sistema de armazenamento de desenho codificado por sua mãe com o objetivo de aprender as suas práticas de tecelagem em um momento de necessidade após o seu falecimento. Apresento em detalhes o funcionamento da tecnologia do tear manual laociano, descrevendo como as partes de seu sistema permitem a produção, armazenamento, recuperação e transferência de complexos de dois desenhos de trama têxteis suplementares geométricas tridimensionais entre os membros de uma comunidade de prática.

Palavras-chave: Etnomatemática; Tecidos; Desenho; Armazenamento de Dados; Aprendizagem Situada.

1. Introduction

The social practices of applied mathematics are an integral part of both economic mathematics and skilled weavers of Lao PDR, in their production of woven two dimensional geometric designs, thus, we find "the manifestation of mathematical creativity'" (D'Ambrosio, 1989, p. 7). This creativity, in the case of the Lao weavers, is

passed down among females in the community of practice through the encoding and storage of geometric designs (two-dimensional geometric representations of social life, the natural world, and spiritual practices/beliefs). The woven textile designs constitute a form of visually communicating among people who share a common sartorial geography (Tarlo, 2010), and the loom constitutes a tool in the hegemonic process of the people and the single-party state's production of an imagined community and Lao national identity (Anderson, 1991). On the periphery of the urban centers of Lao PDR, one is still able to find villages in which the combined practices of handloom textile production and seasonal agricultural production weave a social safety net.

I have been following the transformations in the life of one family of weavers over the course of nineteen years, exploring how the practices of weaving in the shade under the home produced a social safety net for the extended family, enabling the provision of health care, child care, education, hospice care, and the career development that positioned young women in the family on trajectories that lead away from the loom, the home, the country, and the very practices of weaving that were at the foundation of their ability to be regionally and globally mobile.

In this paper I focus in on one particular aspect of the family's weaving: the loom. Specifically, my goal is to share how aspects of the Lao long heddle system are operated in order to store and replicate two dimensional geometric designs, and how such a system enables the passing down of mathematical practice among generations of women engaged in longstanding communities of mathematical practice outside the walls of the school.

1.1. Handwoven Fabric and the Handloom in Lao Society

Handwoven fabrics with supplementary warp designs are fairly ubiquitous aspects of social life among the lowland Theravada Buddhist Lao (Bounyavong, 1993; Bounyavong, 2001; Bounyavong, Pathoumvanh, & Chanthachit, 1995). Handwoven fabrics with supplementary weft designs are key elements of many of the contemporary spiritual practices within the boarder that are thought to predate the arrival of Buddhism (Cheesman, 2004; McIntosh, 2005).

For women, a handwoven skirt and shoulder cloth (*phaa biang*) are the expected requisite attire for temple visits, and any sort of ceremony involving the presence of monks or community spiritual leaders (e.g. spirit calling ceremonies for health, birth, travel, etc., life's rites of passage, merit making activities such as providing food to monks on their daily morning alms rounds in the village) (Cheesman, 1988). Figure 1 shows a shuttle holding a spool of white silk, resting on warp threads with a partially woven continuous supplemental weft of a river dragon patterned Lao shoulder cloth.

Figure 1. Weaving a river dragon patterned Lao shoulder cloth

The handwoven skirt alone is the required attire for just about every civil service job and a woman's visit to government institutions and ministries[1]. Figure 2 shows a Lao bride and groom wearing handwoven textiles on their wedding day in 2007 and figure 3 shows a child wearing handwoven textiles at the That Luang Festival in Vientiane in 2005.

Figure 2. A Lao bride and groom wearing handwoven textiles on their wedding day

Figure 3. A child wearing handwoven textiles

[1]For additional illustrations see Connors (1996).

Vientiane, as the capital city, is a hub of Lao contemporary fashion, and the hand woven supplementary weft designs of a woman's *sin* (tube skirt) often act as a non-spoken sartorial communicator denoting social status, wealth, rank with in an institution, urban fashion consciousness, etc. Soon after a particular design becomes popular in the market, weavers around the city will begin to replicate the design, the replications will often saturate the market, causing a loss of interest among customers and a drop in prices for the pieces, and, as a result, new designs and revived older designs will come to the fore. Weavers on the outskirts of the capital city are engaged in a constant cyclical process of creating/replicating/reviving supplemental warp designs in order to meet market demands.

1.2. Mae Koon's Frame Loom and the Relations that Revolved Around it

Frame looms (Figure 4) are widely used among the politically dominant lowland populations in the Lao PDR. Similar looms are also found across the Mekong River among the wet rice growing populations of Thailand (Gittinger & Lefferts, 1992; McIntosh, 2007; Songsak & Naenna, 1990).

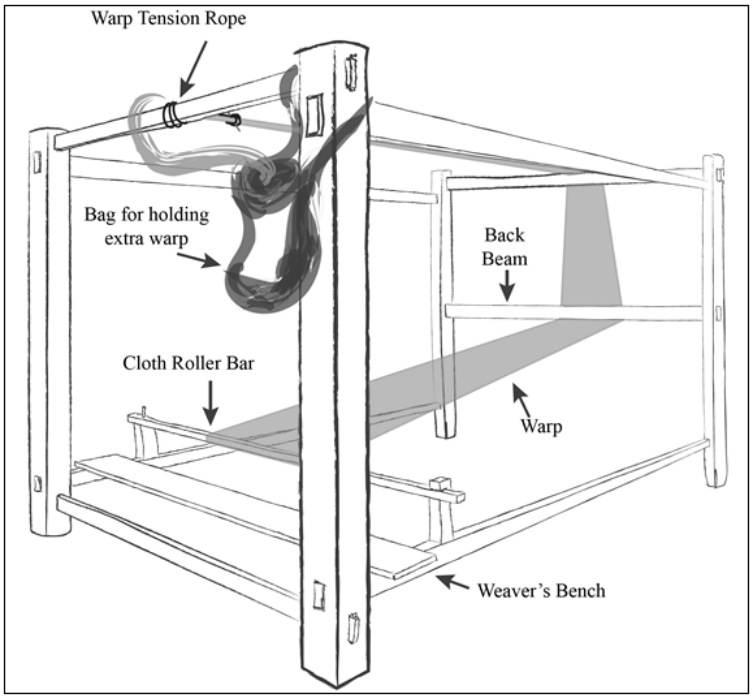


Figure 4. The Lao frame loom

Weaving techniques and technology are often passed down within families through the matrilineal line (Nanthavongdounsy, 1996; Ngaosyvathn, 1995). The loom upon which this paper focuses was located in the shade underneath a house high on stilts, which was, at the time my research started, in 1997, on the periphery of Vientiane, the capital city of Lao PDR.

Koon was the eldest daughter in a family of six children. Her father, a paratrooper during the American war, had passed away some years before, leaving Koon's mother in the difficult position of raising four girls and two boys on her own. Koon was the type of child that everyone in the village seemed to know. She always stood out in a

number of ways, for one, she was exceptionally tall for her age. Her long legs enabled her to reach the treadles of the loom and start weaving alongside her mother at an early age. She was quite verbose, with a quick wit and a much-appreciated observational sense of humor. Koon was not the eldest child of her mother, her two brothers were both older than her, however, she was the child who everyone in the village seemed to know, and hence Koon's mother was known as Mae Koon (*Koon's mother*).

Mae Koon had exceptional skills in weaving supplementary weft patterns of fine silk and *Japanese silk* (a translation of the term used by Morning Market shop owners who sold brightly colored rayon threads to weavers who were unable to read English). By the time I met Mae Koon she no longer had to travel to the market to sell her textiles herself, rather she was fulfilling orders placed most often by entrepreneurial neighbors, Yaa Mae Phuu Thon (the wife of a designated revolutionary war hero), Phaa Fuen (a slightly older woman with considerable land ownership in the village), Mae See (a talkative friend from a few houses down the dirt roadway towards the direction of Phaa Fuen's rice fields). Each of these women would survey the market for popular styles and designs, and Koon and Mae Koon would set to work picking the supplementary weft designs, and fulfilling the orders.

The income Mae Koon and Koon generated through their weaving supported the school-based education of the youngest child in the family, See. Mae Koon was determined to have See graduate from high school, which meant See was not spending time at a loom. The formerly centralized economy of Lao PDR was undergoing rapid change with the rather recent introduction of a market based *New Economic Mechanism* (Bourdet, 1994; Than & Tan, 1997), and See's family saw school attendance as the important pathway towards an economically viable future. See's hours at school, and hours attending to homework after school, meant See was the first of Mae Koon's girls who wasn't learning to weave through daily practice as a child. Figure 5 shows the family altar to Mae Koon, with a portrait I took of her working at her loom.

Figure 5. The family altar to Mae Koon (Photograph by Dalounny Ponsouny, 2016)

In the year 2000, Mae Koon passed away from complications related to diabetes. Without her contributions to the family income, her children were facing a considerable amount of financial difficulty. As a result, See, who was fresh out of high school, began to weave. On my first visit to the family after Mae Koon's passing, I was surprised to find See at her mother's loom, slowly working her way through a very complex design. Standing next to See, I recognized the design taking shape on her warp, an elephant pattern that I had seen her mother weave a number of years before.

I asked See if I could record her at work, wanting to capture how her hands moved slowly across the warp adding discontinuous weft threads in a manner that was not as smooth and deft as her mother's, as she was still learning. Koon jokingly asked me why I wanted to record See, humorously telling me that See was not good at weaving yet, saying See was still learning, producing her mother's designs as she learned to weave. I was fascinated to observe how elements of mathematical practice were handed down to See, how her mothers' design storage system was literally removed from her mother's loom, bundled up and stored away for a number of years, then unbundled when it was time for See to learn, and placed back on the frame loom for See to practice her skills to perfection. Figure 6 shows one of Mae Koon's bundled design storage systems on a wrapping cloth, complete with comb, AB heddles, and long heddle.

Figure 6. One of Mae Koon's bundled design storage systems (Photo by Dalounny Phonsouny, 2016)

In the sections below I explain the components of the Lao loom that enable Lao weavers to produce, store, reproduce, and pass to others their complex woven geometrical designs. These are the tools and technology through which young women like See learn geometrical pattern making from the elders in their community. This form of mathematical learning, through legitimate peripheral participation in an ongoing community of practice takes place at the loom, outside of the village school, and outside school hours.

I start the description of the warp as it trails across the top of the loom and down to the cloth roller bar at the bench where the weaver sits, and then I move up the warp, away from the weaver and cloth roller bar, describing the elements of the technology that have long enabled Lao weavers to create their complex woven geometrical patterns. The descriptions are intended to help the reader understand the practices of woven geometric design, the technologies that enable these designs and design storage, and the tools through which young women enter into the social practice of geometrical design production and reproduction.

2. The Technologies that Enable Two Dimensional Geometric Design Storage and Reproduction

There are some technologies that enable the two dimensional geometric design storage and reproduction in the Lao loom.

2.1. The Warp

The weaver sits on a bench at one end of the loom with one end of the warp attached to a horizontal beam above her head. Figure 7 shows the operational elements of the Lao frame loom with a warp attached.

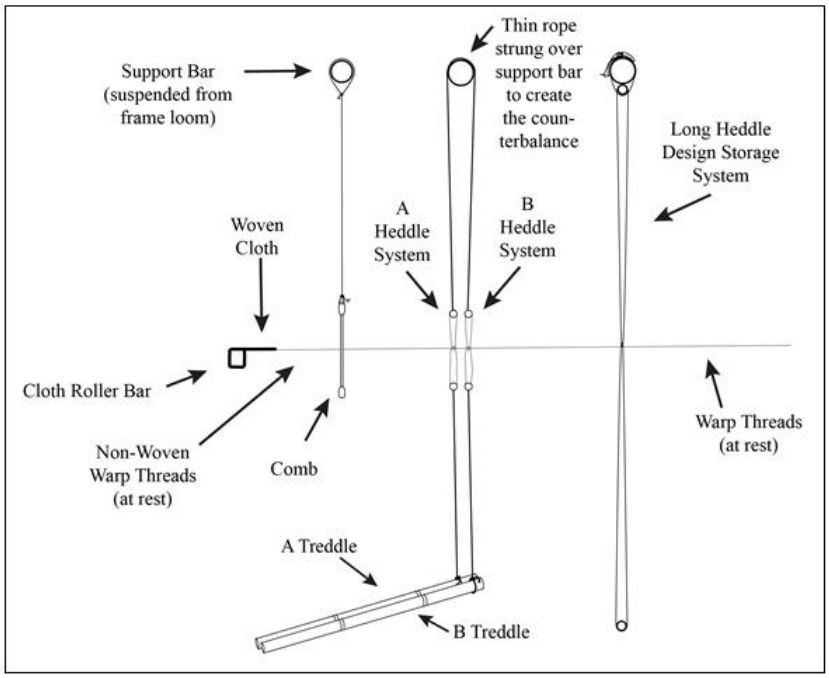


Figure 7. The operational elements of the Lao frame loom

When Mae Koon started weaving on a new warp, the bulk of her warp threads were carefully knotted in to a bundle and stored in a bag hung off of one of the vertical posts of the loom above the bench. Outside of the bag at the top level of the loom the warp threads extend across the length of the loom, over a back beam at the top of the loom, then down under a back slightly above the midpoint on the far end of the loom. Coming out of the bag, the warp threads are bundled into what is essentially a loose ropelike collection of threads. The warp threads begin to be spread out in a plane by crossing over the top back beam, and by the time, they are down to the bottom back beam they are the width of the final piece of fabric. Figure 8 shows Sun, a young weaver in Vientiane, winding the first meters of silk onto a warping frame as she creates a new warp for her loom in 2008. The warping frame is leaning against Sun's frame loom.

Figure 8. Sun winding the first meters of silk onto a warping frame

From the lower back beam to the cloth roller bar, the threads of the warp pass through 1) a long heddle system (which is used to store and produce geometric patterns), 2) a short counterbalanced foot operated heddle system (used to create a plain weave), and 3) a comb/batten. Each of these three devices is suspended from its own support pole hung from the loom frame perpendicular to the warp. Coming through the comb, ends of the threads are grouped into small bundles and tied together, and a long thin stick is placed through the knotted bundles.

Once the long heddle, the short heddle and the comb are hung in place suspending the warp, this stick with the attached thread ends is placed into a grove in the horizontal cloth beam and the beam is rotated towards the weaver a number of times with the warp threads drawn across the top of the beam. In this way, the pressure of the threads rolled around the cloth beam holds the stick and warp in place. Final adjustments to the height of the long heddle system, the short counterbalanced heddle system, and the comb are then prepared to be made. *Figure 9 shows a w*arp threads passing through the comb where the weaver is adding discontinuous supplementary weft to threads to form the cloth. The cloth is rolled around the cloth roller bar shown at the bottom edge of the image above.

Figure 9. Warp threads passing through the comb (Photo by Dalounny Phonsouny, 2016)

The cloth roller bar stretches across the width of the loom, just in front of the weaver's bench, above the weaver's lap, at a level around the height of the lower ribs of a middle-aged weaver of average height. The warp is affixed to this bar with the stick that holds all the threads in place. One end of the cloth roller bar is typically held in place by two wooden posts that are inserted into the support beams that run the length of the loom upon which the weaver's bench rests (Figure 4). One of these posts often has a single upright peg on the top – and this peg fits snugly into a hole drilled entirely through the cloth roller bar on that end. In addition, the other end of the cloth roller bar fits into a square cut out in the opposite upright post (Figure 4).

In Lowland Lao society weavers are predominantly gender identified as *female*. It is extremely rare to find people who are gender identified as *men* weaving on lowland Lao looms. As a result, the terms I use in this paper in relation to the weaver will be female. Once the warp threads are secured on the cloth beam, the weaver would take the rope of warp above her head, tie it into a slip knot, insert a wooden stick into this knot, attach a rope around the stick and the knot and firmly pull on the rope, creating tension in the warp, and tie the warp into place on the beam above her head.

2.2. The Comb

The *comb*, be it made of plant materials or a store bought metal comb, is enclosed in a wooden frame. The wooden frame gives the comb added weight and provides a firm grip for the weaver to use it as a batten to tamp in the weft threads. Two holes are drilled in the top half of the frame, with one located near each end. A separate thin piece of rope is tied through each hole, and the opposite end of the ropes are tied to a bamboo pole support beam either laid across the top of the loom, or suspended from the frame, perpendicular to the warp. The comb is suspended so that the warp threads pass through teeth of the comb halfway between the top and the bottom of the frame. The comb is swung, usually twice, into the weft threads to tamp into place the threads laid down by each pass of the shuttle. Figure 10 shows a comb from a Lao loom.

Figure 10. A comb (Photo by Dalounny Phonsouny 2016)

This tamping of a plain weave by a skilled weaver forms a rhythmic *boom boom* pause *boom boom* pause *boom boom* beat. As the skills of a young weaver develop, you can hear her skills improve in the rhythm of her tamping beat. An audible break in the rhythm is a good indicator of someone (including a skilled weaver) running into problems (such as a warp thread breaking which must be retied, or the sudden realization that a line of weft was incorrectly inserted in to the warp).

The comb is designed to be the width of the fabric, but one finds that is common for weavers to use or reuse a comb that is slightly wider than the final width of the warp. As a result, one often sees the warp passing through a comb with a number of

centimeters of extra-unused teeth on either side of the warp threads. *Figure 11* shows an AB warp thread pairs pass through each space between the teeth of the comb.

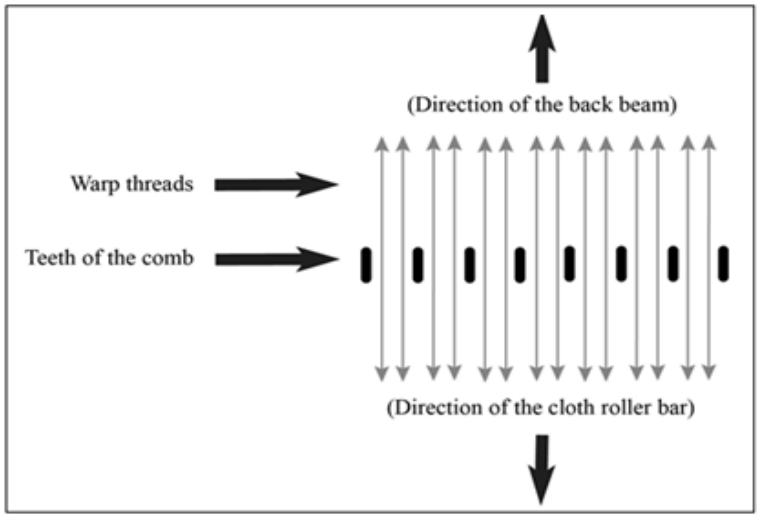


Figure 11. An AB warp thread pairs

Adjacent warp threads are inserted through the spaces between the teeth of the comb in AB pairs (an explanation of AB threads is provided in the section below on the AB heddle system). The comb structure functions to keep the pairs of warp threads aligned, evenly spaced and in their in proper place as the cloth is being build up line by line with the insertion of the weft. The hanging comb is used to tamp/beat the weft threads into place after each pass of the shuttle, and after each line of the design is woven in to the warp. Moving up the warp away from the weaver and past the comb, one finds the treadle operated heddle system that opens the AB shed pattern for producing a plain weave cloth.

2.3. Treadle Operated Counterbalanced Short *AB* String Heddle System

Next, the strings of the warp pass through a simple foot peddle operated short string A and B counterbalanced heddle system. Mechanically, the small heddle system is a very simple device, but it is rather intricate in the minute aspects of its handcrafted construction. The Lao AB heddle system is a foot operated device that functions to lift every other warp thread, while simultaneously pulling downward the non-lifted threads. This creates a space (a *shed*) between the two layers of threads through which the weft threads are inserted into the warp. Figure 12 shows an AB string heddle system opening a shed in the warp.

Figure 12. An AB string heddle system (Photo by Dalounny Phonsouny, 2016)

To understand how the heddle system functions, it is helpful to think of each of the hundreds of parallel warp threads as being represented by one of the alternating *A* and *B* letter labels. Starting from the left edge of the collection of warp threads, which are organized in parallel lines on a single plane, the first thread of the warp would be labeled an *A* thread, and that single thread would pass through an interlinked string loop heddle tied to the A heddle rod set. Figure 13 shows the A warp threads pass through the double loops of the A heddle system, the B warp threads pass through the B heddle loops.

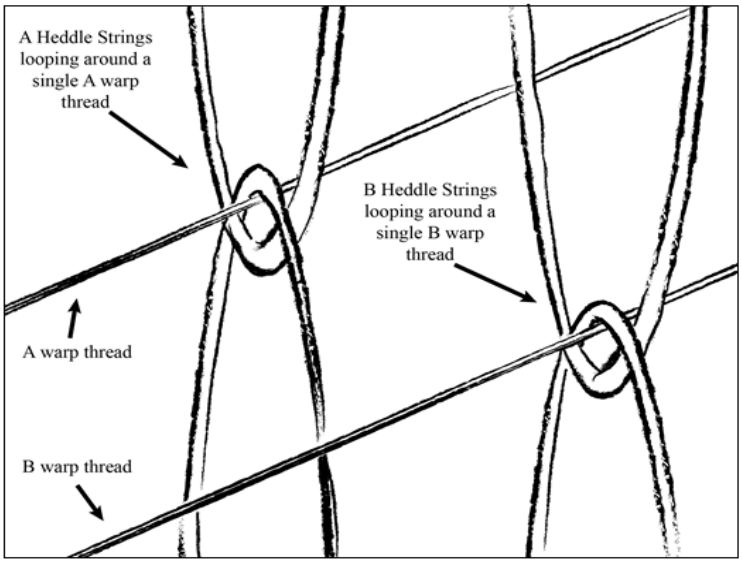


Figure 13. The A warp threads pass through the double loops of the A heddle system

The next thread immediately to the right of this first *A* thread would be labeled a *B* thread, and it would pass through its own interlinked string loop heddle tied to the B heddle rod set. Figure 14 shows the division of warp threads as the pass from the comb into the AB heddle system.

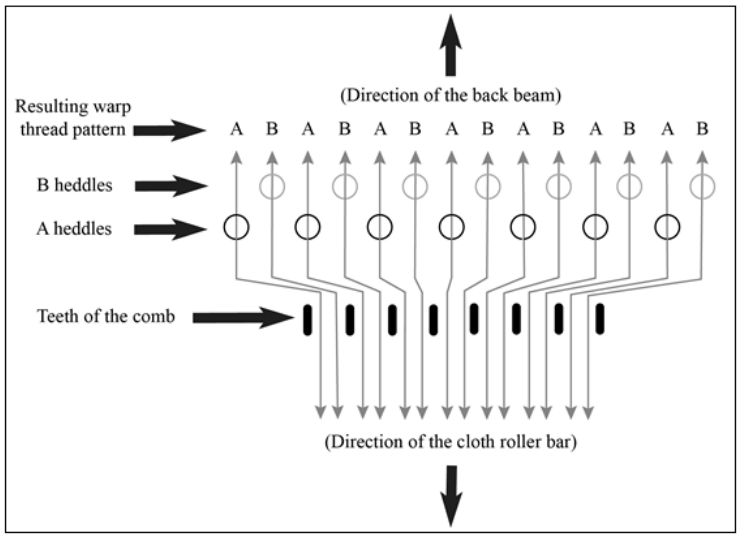


Figure 14. Division of warp threads

The thread immediately to the right of the first *B* thread would be the next *A* thread, repeating the ABABABABAB pattern, assigning alternating threads to either the A or B heddle rod systems.

The counter balance mechanism is formed by using two pieces of thin rope of equal length looped over a bamboo suspension pole, and attached to the A and B heddle rod systems. One end of the first length of thin rope is tied to the top right end of the A heddle rod system, and the other end of this length of rope is tied to the top right end of the B heddle rod system. Figure 15 shows the operation of the foot operated counterbalanced AB heddle system.

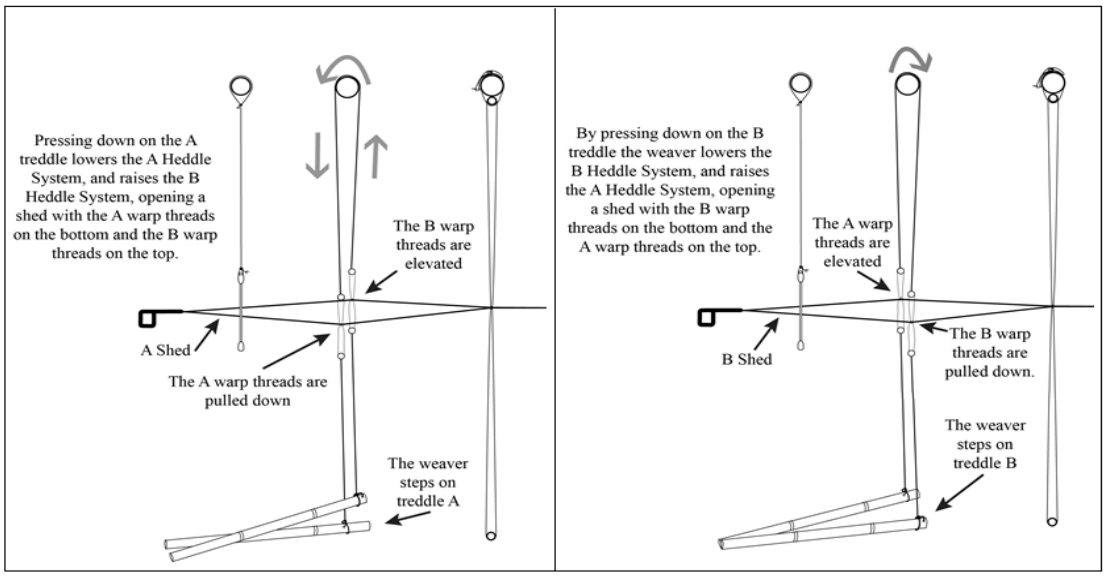


Figure 15. Operation of the foot operated counterbalanced AB heddle system

The second rope has one end tied to the top left side of the A heddle rod system, and the other end tied to the top left side of the B heddle rod system. Figure 15 also shows the ropes are then draped over the bamboo suspension pole, with the A heddle rod system hanging down on the thin ropes on one side of the suspension pole, and the B heddle

rod system counterbalances the weight of the A heddle rod system, by hanging down attached to the opposite end of the thin ropes on the other side of the suspension pole.

Because the two heddle systems are linked with the string that passes over the bamboo support bar suspended from the loom's frame, when B heddle rod set is lowered (by the weaver pressing down on the bamboo pole treadle attached to the lower B heddle rod), the A heddle rod is simultaneously lifted. This opens up a *shed* between the A and B warp threads, with the A threads constituting the top of the A shed, and the B warp threads constituting the bottom of the shed. Figure 16 shows the illustration of the constitution of cloth produced with an AB heddle system

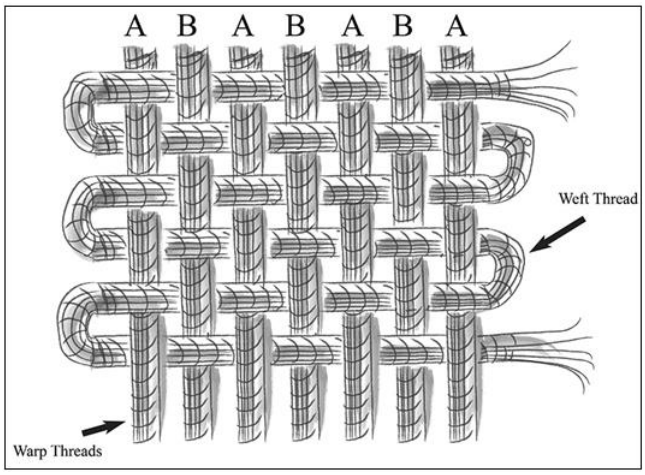


Figure 16. Illustration of the constitution of cloth produced with an AB heddle system

The weaver will pass a shuttle carrying the spool of weft thread through this opened shed, laying in place a weft thread. When the weaver moves her foot off of the B treadle the warp threads return to their horizontal resting state. At this point, the weaver will tamp into place the weft threads by swiftly and firmly sliding the comb towards herself and the cloth beam. Once this weft thread is tamped into place, the weaver will step on the A treadle, lowering the A heddle rod set, and simultaneously raising the B heddle rod set, opening up a second shed, with the A warp threads now on the bottom, and the B warp threads forming the top of the shed (Figure 15). The weaver will then pass the shuttle back to the other side of the warp, unspooling into this shed the weft thread. Once the shuttle has passed quickly through this opened shed, the weaver will remove her foot from the A treadle, allowing the warp threads to return to their horizontal resting state, and she will once again slide the comb towards the cloth beam, tamping the weft thread into place. This process is repeated over and over again, producing a simple plain weave (tabby weave) fabric (Figure 16).

As the amount of woven fabric filling the space between comb and cloth bar increases, the weaver will occasionally stop, loosen the tension on the warp, roll the woven cloth onto the cloth bar, reset the warp tension (through pulling down on the bundled warp threads above her head) and tie the warp tightly in place. A plain weave, using the simple AB heddle system, is one if the first things a young woman would begin learning to produce when she sits down at the loom at a young age. The next piece of technology as one moves up the warp away from the weaver's bench requires significantly higher skills to masterfully operate. This next technology is the *long heddle* design production and storage system.

2.4. The Long Heddle System

Lowland Lao weavers often create their designs using a supplemental weft technique, in which specific threads of the warp are lifted out of the AB pattern, creating a shed that has *floats* (specific warp threads in groups over which the weft thread floats, outside of the normal AB pattern). Figure 17 shows Eui Kim, Koon's cousin (left) and Dalounny Phonsouny (right) connecting the ends of a placeholder string to the nails on the posts hanging down beside the long heddle system in 2007.

Figure 17. Eui Kim (left) and Dalounny Phonsouny (right) connecting the ends of a placeholder string to the nails on the posts

The long heddle system is the lowland Lao weavers' geometrical design storage and reproduction tool. It is used to store and reproduce sheds with purposefully designed supplementary threads that float over designated warp threads. As these supplementary weft threads are stacked into the warp the weavers are able to create their geometric patterns. Figure 18 shows that unlike the AB heddles system, and returning to the pairing one finds in the comb, each heddle of the long heddle system operates an AB pair of warp threads simultaneously.

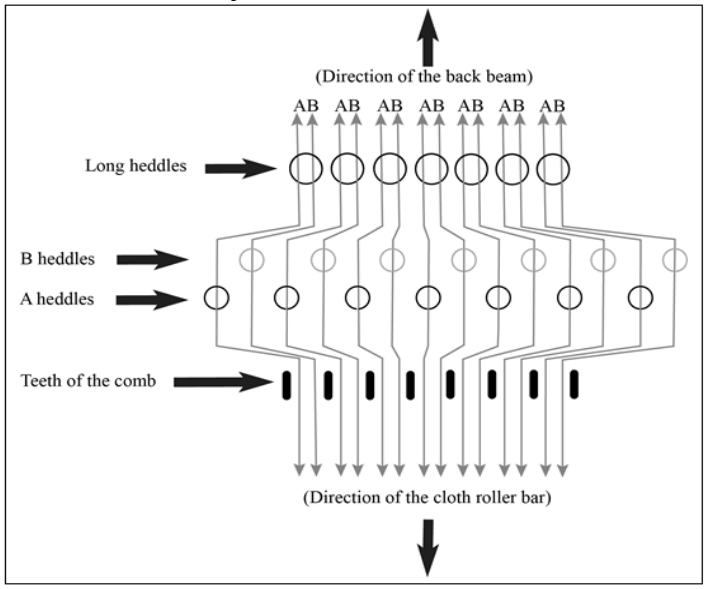


Figure 18. Heddles of the long heddle system

Using the comb as her guide to determine which AB thread pairs are to be lifted together, the weaver uses a needle or her fingernail to carefully count and lift the threads that will constitute one line of her design. The weaver lifts the threads upwards,

as the side cloth that faces towards the ground will eventually be the outward face of the fabric. As she picks and lifts the select AB pairs she keeps these elevated by inserting a thin flat smooth piece of wood or bamboo (a place holder stick around 1cm or 2 cm wide) into the shed she is creating to hold these selected threads above the non-selected warp threads. This extremely tedious and time-consuming process requires good eyesight and considerable patience. Women often age out of design picking, as vision changes, and it becomes more difficult to discern the individual threads of the warp. Figure 19 shows an illustration of how a weaver would use the tip of a needle to pick AB pair warp threads at the start of one line of a design.

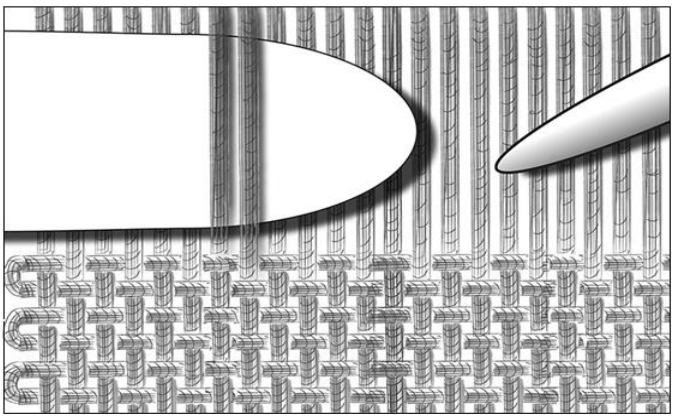


Figure 19. Illustration of the use of the needle

The object on the left of figure 19 is a thin smooth piece of bamboo, used to maintain the elevation of the selected AB pairs of warp threads when picking a design. The object on the right of figure 19 represents the tip of a needle used to separate and pick up the fine silk threads of the warp as the bamboo is slid underneath to maintain the shed that is being picked. The weaver will often start picking a single line of the weft at one side of the warp and work her way across to the opposite side, sliding the placeholder stick in as she goes. Once all the selected AB thread pairs are on top of the placeholder stick, the stick is lifted, elevating the selected warp threads, creating a shed. The comb is pulled forward towards the cloth bar and on the opposite side of the comb a flat, though much wider piece of wood (about 11cm wide), shaped much like a double-edged sword blade, and is slid into the newly picked shed. Figure 21 shows the insertion of the flat insertion of the sword into the shed and then it turned up on its edge to open the shed wide.

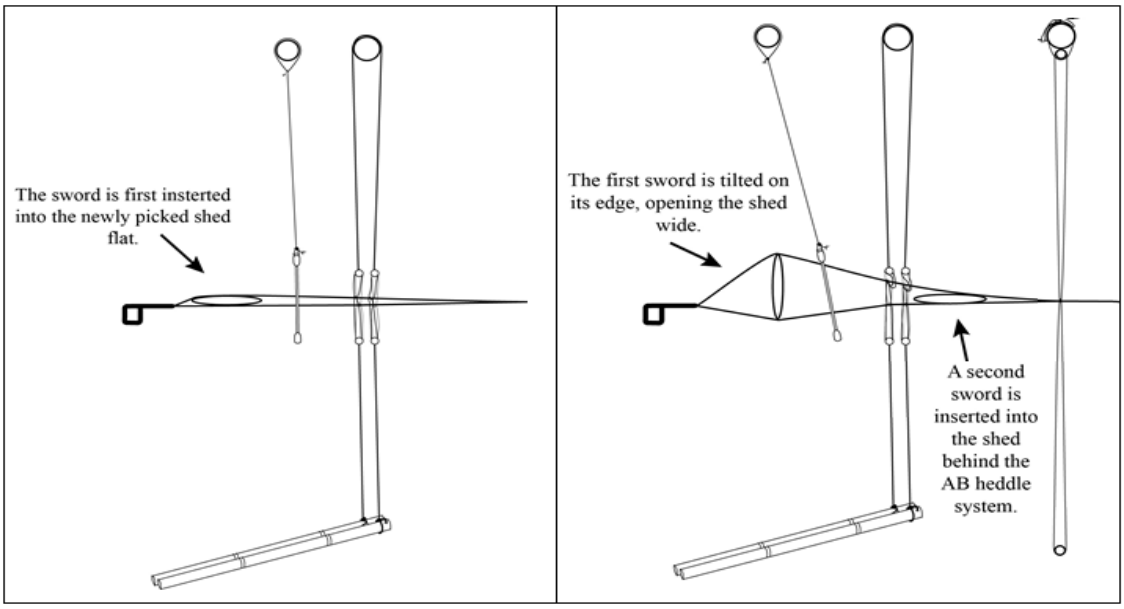


Figure 20. The insertion of the sword into the shed flat

The weaver then uses a stick held against the backside of the long heddles to pull the string heddles down the warp towards her and the comb. Because the top of the long string heddles is attached to a support bar the top of each long heddle remains stationary. By pulling the part of the long string heddles that loops around the warp threads towards the comb with the *sword* on edge to open the shed, the weaver creates a situation in which the string heddles that are attached to the non-elevated warp threads become taunt, while the string heddles that loop around the lifted threads remain relatively relaxed and loose. The weaver will then take the stick and place it across the front of the long string heddles, about 10 to 20 centimeters above the warp, and gently push the mid-section of all the long string heddles a short distance away from her.

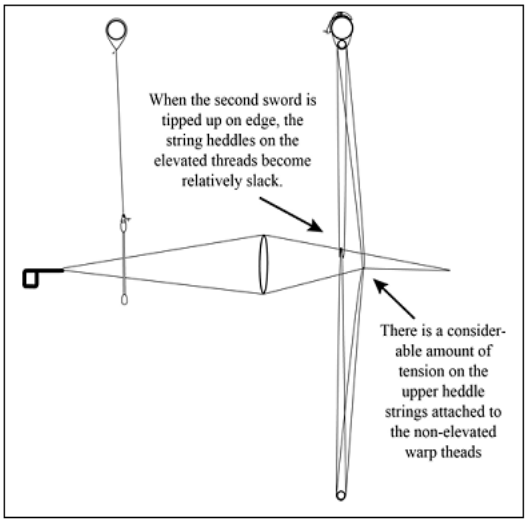
By doing this, the part of the taunt long string heddles that loops around the non-elevated warp threads is pushed away from her up the warp towards the far end of the loom. Because long string heddles that loop around the elevated warp threads do not have tension on them, the part of each of these heddles where the two strings loop around the warp thread remains largely in place. By pushing the tense heddles up the warp away from the comb and leaving the loose heddles in place, a space is created between the heddles of the non-elevated warp threads and the elevated warp threads.

From the side of the loom the weaver will carefully insert a stick into this space, using the tip of the stick to gently tap the elevated heddles towards the comb, and the non-elevated heddle strings away from the comb. Keeping in mind that the eventual outward face of the fabric is facing downward while on the loom, we can understand that the elevated heddles close to the comb loop around the warp threads over which the floats of the supplemental weft will pass (Figure 21).

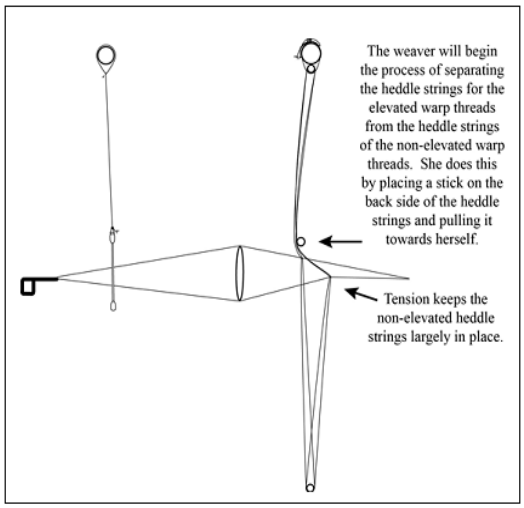
In this manner, the weaver separates out a row of string heddles (moving them towards the comb) that she will later be able to manually lift to reopen this particular shed for this one line of the supplemental weft design. At this point the weaver will insert either a placeholder stick or a piece of string (tied in a loop the length of which is a little wider than the warp) into the space between the relaxed elevated heddles, and the taunt non-

elevated heddles. This string or stick placeholder preserves this shed and the line of design.

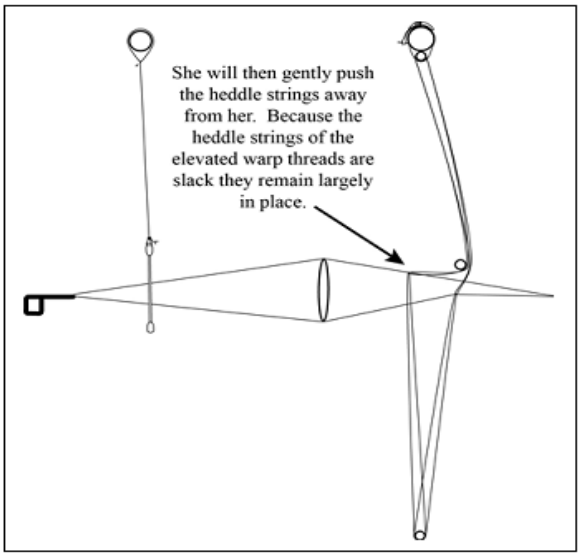
This placeholder stick/string is then lifted up into the heddle system above the warp and held in place. In the heddle above the warp, the sticks are often held in place by a rubber band hook system. When strings are used as the placeholders, the looped ends of the strings are often hung over nails driven into two pieces of wood that hang down from the top of the loom on both sides of the heddle system. Figures 21, 22, 23 e 24 show sequences *no. 1, no. 2, no. 3, no.4* through which a picked line is stored into the long heddle system with a placeholder string.



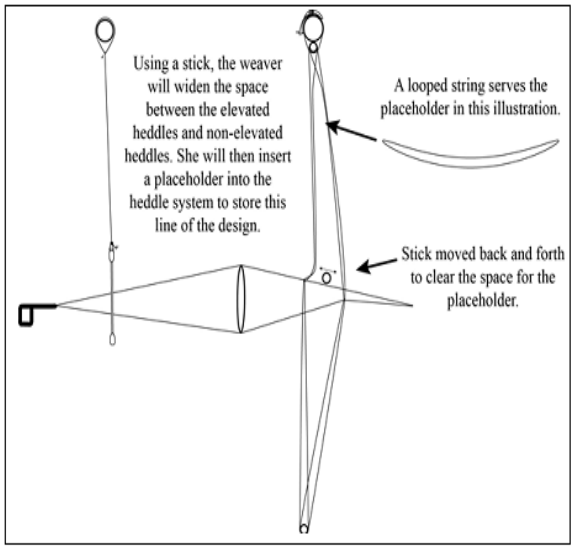
Figures 21. Sequence *no. 1*



Figures 22. Sequence *no. 2*



Figures 23. Sequence *no. 3*



Figures 24. Sequence *no. 4*

Once one line of the supplemental weft design is stored, the weaver will move on to picking the next line of the design. The process of picking, storing, and perfecting a complex design may take more than a month. What might be clear by now is the complex type of thinking that the weaver must do in order to pick her design. She must pick and lift what is essentially a negative image of the design she wants to appear on the outward face of the textile.

So not only does the Lao weaver have to think of the geometrical image line by line as she creates it, but she must also think of the inverse image of the eventual design as she is facing the back side of the fabric that she is creating. As more and more lines of the design are picked, the heddle system will fill with placeholder strings, or placeholder sticks. Generally, with complex designs, a weaver will have to switch from using placeholder sticks to using placeholder strings, as the strings occupy considerably less space in the long heddle system.

The weaver needs to only pick and store one half of a design up to its horizontal midpoint, as the way the long heddle storage system is created, the weaver produces a mirror image of the first half of the design once the weaver reaches this horizontal midpoint. Once the weaver has picked all the lines of the supplemental weft design and stored these in the long heddle, she will weave a small test piece, proofreading her work, checking for aspects that may be off. Typical recurring errors include a warp thread that does not match the AB pattern (in this case a long vertical run is evident throughout the design), or supplemental weft floats that are in the wrong place, missing, too long, or too short. As she detects errors, she will correct these as she works through the test piece.

To understand how this works, below we will look in detail at the process in which the long heddle storage system using strings as placeholders is used to produce repeated horizontally symmetrical geometric designs in a Lowland Lao shoulder cloth. The shoulder cloth (*phaa beiang*) is what Lowland Lao Buddhist women will typically wear to the temple, and for ceremonial purposes such as providing offerings to the Buddhist monks as the monks make their alms rounds through the villages each morning.

The weaver will start the piece by leaving about ten centimeters of warp threads unwoven. These unwoven warp threads will later be braided to form the decorative fringe on one end of the shoulder cloth. After the unwoven warp fringe, the weaver will begin weaving a simple AB pattern plain cloth for a number of centimeters. The amount of plain weave is dependent upon the design of the weaver's final piece. This plain weave builds a lower edge that will hold the supplemental weft design in place.

At the point where the weaver wants to start the first line of the supplemental weft pattern, she will tamp into place the AB weft thread and then reach up to the lowest placeholder string in the long heddle system. With her right hand, she will detach the right end of the looped string from its nail and hold it firmly. With the left hand, she will detach the left end of the lopped placeholder string and hold it firmly in her hand. With a grip on both ends, she will lower the string, with one hand on each side of the heddle system, bringing the string down to the level of the warp.

Once at the warp she will pull the string towards herself – pulling all the heddle threads that constitute the first stored line of the design towards the short AB heddle, the comb, and herself. Still holding the ends of the string loop in either hand, she will then push long heddles on the opposite side of the string away from herself towards the other end of the loom. By doing this, she is moving the heddle strings for the warp threads that must be elevated towards herself and pushing the heddle strings for the non-elevated warp threads away from her, creating a space between the two. Figures 25, 26, and 27 show illustrations *no. 1*, *no. 2* and *no. 3* of the use of a stored line of design.

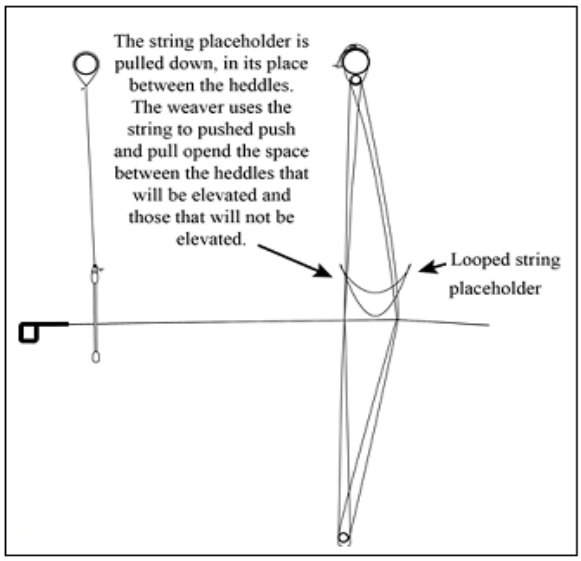


Figure 25. Illustration *no. 1*

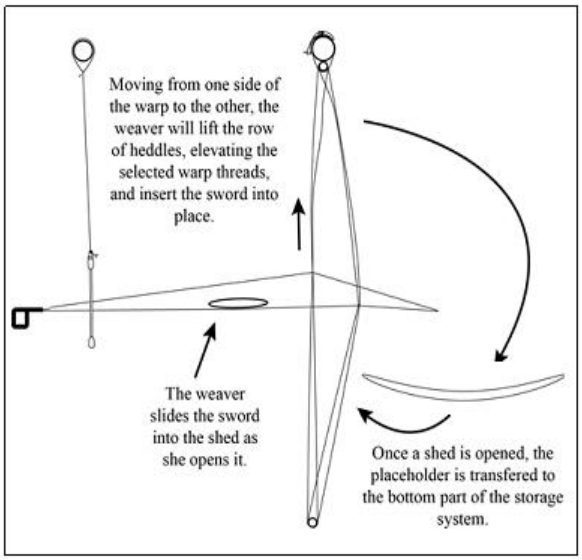


Figure 26. Illustration *no. 2*

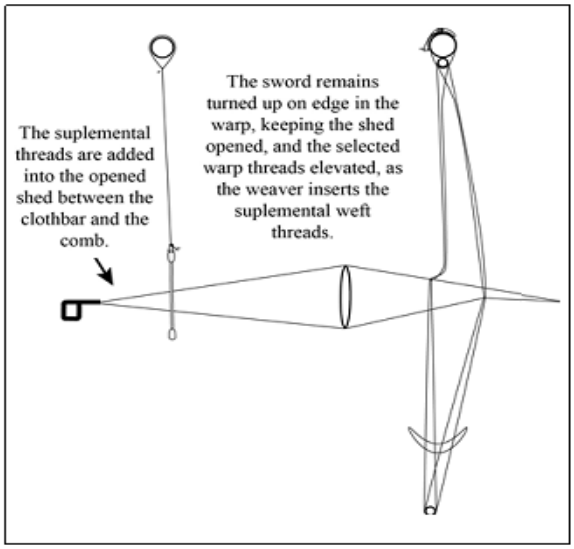


Figure 27. Illustration *no. 3*

At this point, a weaver will often drop a placeholder stick into the V shaped space between the two separated groupings of long heddle threads below the warp. This placeholder stick is to insure that the separation between the two groups of long heddle strings is maintained. She will then carefully transfer the string from the space between the separated portions of the heddles above the warp, to the space between the heddle strings below the warp. As she does this, she will loop the right end of the placeholder string over a post rising up from a stand on the ground on the right side of the heddle system, and loop the left end of the placeholder string over a post rising from the stand on the left side of the long heddle system.

With the placeholder string securely in the long heddle system separating the two elevated warp thread heddles from the non-elevated warp thread heddles for this line of the design, the placeholder stick can then be removed. What the weaver has done in this procedure is 1) open up pull forward the heddle strings that must be lifted to form the shed for the first line of the design, and 2) transfer the storage of this line of the supplemental weft design into the long heddle system on the lower side of the warp. With the long heddle strings that must be elevated pulled towards the weaver, she is ready to start the process of opening the shed for this first line of the design.

Holding the wooden *sword* (*mai laap*) in her non-dominant hand, she will use her dominant hand to carefully grab the first palm-width handful of the to-be-elevated long heddle strings, starting at the non-dominant hand side of the warp (e.g. for a right handed weaver she will use her right hand to grab a palm-width bundle of the to-be-elevated long heddle strings starting on the left edge of the warp). With these heddle strings firmly in hand she will lift the selected warp threads, opening a shed. Using her non-dominant hand, she will insert the wooden sword into this shed so it is lying flat on the non-elevated warp threads below it, with the elevated warp threads held above the top side of the blade.

Then, she will stop inserting the sword when the tip of the sword is just a few centimeters past the last elevated warp thread. Moving from left to right, the weaver will release the first bunch of long heddles, allowing the warp threads to rest on the top side of the sword, then grab the next palm-width handful of string heddles in this line of the design, lift those, and slide the sword under this next bunch of elevated warp threads. She will repeat this process across the width of the warp, until the sword occupies the shed of the first line of the supplemental weft design, with the tip and the end of the sword extending a number of centimeters beyond the width of the warp on either side. At this point, she will tilt the sword up on its edge, opening the shed, and begin to add the supplemental weft threads.

After one line of supplemental thread is in place, the weaver will flip the sword down flat, and pull it out of the warp, closing the shed. She will then tamp the supplemental weft thread(s) in place. Using the AB heddle system, she will step on the A treadle to open the A shed, pass the shuttle through, remove her foot from the treadle and tamp the warp thread into place. Then step on the B treadle, open the B shed, pass the shuttle through the B shed laying down a warp thread, remove her foot from the treadle and tamp that thread into place.

Then, the weaver will reach up to the long heddle storage system and grab both ends of the next placeholder string, lower it to the level of the warp, pull it towards her, and

begin the process of grasping and lifting the selected long heddle strings, using the sword to open the next shed for the next line of the supplemental weft design. When weaving a complex design, for example, one composed of hundreds of lines of supplemental weft; she will repeat this process for every single line of the design. Skilled weavers will work with a dexterity and speed that can only be developed through hours of practice.

There are two primary types of Lao supplemental weft: 1) continuous supplemental weft, and 2) discontinuous supplemental weft. The continuous supplemental weft process is the simplest form of adding supplemental threads to the warp. In this process, the weaver simply loads a shuttle with a spool of the supplemental thread, and passes the shuttle through the opened shed, reeling in to place in the warp a single line of supplemental thread for this one line of the design. Figure 28 shows Eui Kim weaving a naturally dyed silk discontinuous supplementary weft shoulder cloth.

Figure 28. Eui Kim weaving

The practice of adding discontinuous supplemental weft is far more complex. Discontinuous supplemental weft involves using separate, discontinuous, threads added to the warp, rather than using one long continuous thread added with a pass of a shuttle. Weaving discontinuous supplemental weft requires more experience on behalf of the weaver, as intricate thread handling skills are involved. She must have a mental conceptualization of the final design, combined with an ability to envision it (in reverse, as the warp is set up so that she is looking at the back side of the cloth), and the ability to apply this thinking to building multiple two dimensional figures side by side simultaneously, one horizontal line of the weft at a time.

The weaver will begin by opening a shed for one line of the design, then look for the starting point of each element of the design that will be represented by its own separate thread. For purposes of illustration, let us imagine that the weaver is creating a design with multiple side-by-side diamonds of the same shape and size, but she wants to make each of these diamonds a different color. The starting point the weaver is looking for in such a design would be where the lower point of each diamond touches the last horizontal line of the AB plain weave she has just tamped into place. She will select a different colored thread for each of the diamond shapes, and unspool and cut these threads into about a half meter in length. She will then move from one edge of the warp to the other looping and gently tying in place a different colored thread under and

around the two AB warp threads that constitute the lower point of each separate diamond. She would then remove the sword, tamp that line into place, run the shuttle through the AB sheds tamping each of those two lines in place, and then open up the shed for the next line of the diamond design.

The weaver will reach up to the long heddle system, pull down the next placeholder string, and open the subsequent line of the diamond design. This will create the next horizontal line of the diamonds, making the horizontal line of each figure one increment up from the lower tip that was put in place with the preceding process. As the single colored threads are already tied in place, and tamped into the warp with the AB weft threads, she no longer needs to make any knots. She simply must determine which warp threads constitute the threads under which the colored floats must be inserted, in the next line in the progressive building of the diamond shapes.

Mae Koon used a two hand process, with working right to left across the warp she would insert her left pinky finger under the elevated threads, using her right hand to place the selected colored thread over the tip of the left pinky, and then quickly but gently pull the colored thread into the warp, under the selected elevated threads, and out from under the warp threads on the other side, ending the move with her left hand pulling the remaining discontinuous thread downwards towards herself so that it lay neatly in line with the warp threads and over the top of the cloth on the roller bar. Figure 29 shows multiple discontinuous supplementary weft threads lying across the woven cloth as the weaver takes a break in her weaving.

Figure 29. Sun weaving a complex diamond pattern

Once all the colored discontinuous threads of this second horizontal line of the diamond design were in place, the weaver will remove the sword, tamp the line into place, use the shuttle to weave in an A and a B thread, tamping each into place, and then use the long heddle system to open the shed for the next line of the supplemental weft.

Because the last line was inserted from right to left, the weaver will switch hands and pick up the thread on the left side of the design, working from left to right, inserting her right pinky finger under the selected elevated warp threads, and draw the colored thread under these, again ending the quick move by pulling the extra remaining colored discontinuous thread towards herself, laying it gently parallel to the warp threads over the cloth on the roller bar. She will work the supplement weft threads for each line of

each separate diamond in to the warp threads in this way, working pass by pass, left to right then right to left over the warp.

In building the design supplemental weft line by supplemental weft line, the weaver will work her way up through the placeholder strings. Once the heddles for a supplemental weft shed are pulled towards her for elevating, the weaver will transfer the placeholder string to the long heddles below the warp. In this way, she maintains the order and storage of the lines of the design. As she works her way up through all the stored lines of the design, she will eventually reach the last string in the long heddle, which will be the midpoint of the diamond shape. At this, the widest spot in the diamond design, where she forms the left and right side points on each diamond shape at the horizontal midpoint of the diamond, she will bring this last placeholder string down, pull the to-be-elevated heddle threads forward, and, rather than transferring this last string down into the heddle system below the warp, she will bring it back to the top of the heddle system and hook it in place on the nails.

This last line constitutes the point of horizontal symmetry in the formation of the two dimensional geometric diamond patterns. From this point the weaver will work her way down through the supplemental weft placeholder strings now stored in the lower part of the long heddle system below the warp. She will use both hands to lift the placeholder string off the posts below the loom, pull the placeholder string towards herself and the bench, to bring forward the to-be-elevated heddle strings for the next line of the design, and then transfer the placeholder string up into the space created between the heddle strings, and hook it into place on the nails on each side of the long heddle system above the warp, safely storing this line of the design to be used again.

She will lift the selected heddle strings and use the wooden sword to open the shed, add the supplemental threads, tamp them in place, add an A and a B weft thread tamping each into place, and then reach down to select the next place holder string and repeat the process of opening the next shed for the supplemental weft diamond design, moving the placeholder back into place separating the selected heddles in the long heddle system above the warp. Figure 30 shows the use of two long heddle systems for storing a complex ‘pregnant elephant’s design composed of more than three hundred lines of supplementary weft.

Figure 30. The use of two long heddle systems for storing an elephant’s design

A complex design made up of hundreds of supplemental weft threads may require multiple long heddle systems and (with processes of dying the silk, preparing the warp, picking the design) may take the weaver months to complete. Because a heddle system

can only extend so far below and above a loom, weavers producing designs with hundreds of lines may need to build more than one long heddle system on the warp.

3. Conclusion

When it is time for a weaver to retire a design, a segment of the warp threads approximately a meter long will be left in place in the comb, the AB heddle system, and the long heddle system. The ends of these warp threads will be tied so that they do not slip out of any of the heddles or comb. The above the warp part of the heddle systems will be rolled down to the level of the warp, and the below warp heddle systems will be rolled up to the level of the warp, and all will be tied in place. This bundle of comb, heddles and warp can then be carefully rolled up in a piece of cloth and stored away from the elements and vermin (e.g. termites, mice, and rats).

These bundles of mathematical practice will be unrolled when needed, for example, when an older design becomes marketable again, or when a young weaver needs to learn to weave in order to produce an income for her family. The cloth is unrolled, a new warp is prepared on a warping frame, and the ends of the new warp threads are carefully tied to the ends of the old warp threads. The heddles and comb are hung in place, and the end of the warp is affixed to the cloth roller bar, and the stored two-dimensional geometric design system is ready to use again.

With the case of See, she and Koon were able to dust off the bundled designs of her mother, and use these to teach See the practice of weaving complex and valuable fabric. The stored textile practice lived on its utility after Mae Koon's unfortunate passing. The income generated from weaving helped to further transform Mae Koon's family, which proved vital to them as the urban center began to encroach on their peripheral village.

The entire family has stopped weaving now. The house is no longer on the periphery of the city – the urban has sprawled around them, the dirt tract that passed their house and led to the rice fields is now a concrete street, leading to a four lane roadway where the rice fields once stood. The neighborhood's balance of weaving and rice cultivation has been permanently disrupted. The shaded space below the house on stilts, where the looms once stood has been walled in with concrete and bricks.

The space is now a beauty parlor, and high on a shelf sits an altar to Mae Koon, with the image of her sitting at her loom, which once stood in the exact same location. All of the textiles Mae Koon had produced have been sold. However, what remains are the bundles of long heddle systems which constitute years of labor and complex woven geometry. They lie in wait for a future generation of young weavers to discover their mathematical beauty.

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